

# THE RELATION BETWEEN RIPE SLUDGE AND INCOMING FRESH SOLIDS\*

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IT HAS BEEN customary to calculate the capacity of the sludge compartments of Imhoff tanks on the basis of a certain number of cubic feet per capita. Eddy<sup>1</sup> in a paper "Imhoff Tanks—Reasons for Differences in Behavior," read before the American Society of Civil Engineers and discussed by Downes and Skinner, has considered in detail the relation of depth of the tanks to sludge digestion. Downes concluded that "the slot of an Imhoff tank should be placed with due consideration of the progress of digestion which will have been attained at the time when the freshly deposited solids (without shrinkage) have accumulated to a depth equal to the distance between the bottom of the tank and the slot."<sup>2</sup> Mr. Eddy agrees with him that "the slot must be placed sufficiently high to permit the accumulation of sludge in quantities estimated to occur in the time interval required for satisfactory digestion."<sup>3</sup> It is our impression that Mr. Downes had in mind more than sufficient capacity of storage of sludge during the winter months for he calculated the deposition and accumulation of fresh solids in comparison with their digestion.

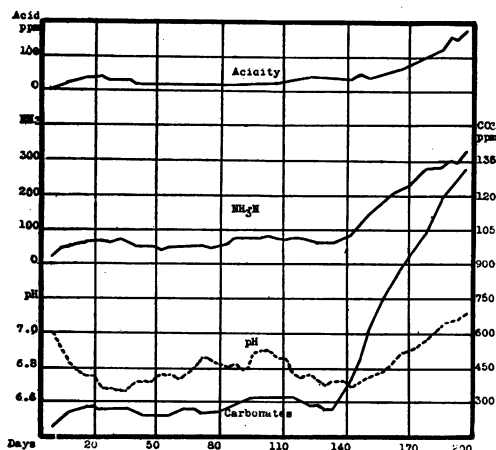
At the suggestion of Dr. Imhoff, the superintendent and chemist of the Plainfield plant, Mr. Downes, had one of his tanks cleaned and altered so that the slots were placed as nearly in accordance with the conclusion cited above as was practically possible. This altered tank was

put into operation anew on April 21, 1924. The bottom of the tank was covered with 30 inches of old sludge for seeding before sewage was admitted. From the beginning of operation this tank was watched closely and chemical, bacteriological and zoological analyses made at frequent intervals. It soon became apparent that sludge digestion was not progressing at the expected and desirable rate. Figure I shows the production of ammonia in comparison with carbonates, total acidity and pH values in the tank during the first 5 months. The first striking feature of this graphical representation is that from the end of April to the end of August practically no changes took place in  $\text{NH}_3$ ,  $\text{CO}_3$  or total acidity production. The quantities of ammonia and carbonates produced were considerably below normal. All our data collected indicate that a minimum of 300 p.p.m. ammonia should be present in the liquid, while 1300–1500 p.p.m. carbonates is correlated with good and rapid digestion. That slight changes occurred in the tank is indicated by the fluctuations in pH values. By the end of August a sudden increase in carbonates occurred followed by an increase of ammonia and total acidity. On September 18 this tank had to be rested on account of heavy foaming and later on, due to the necessity of handling large volumes of sewage in tanks which were working decidedly abnormally, the tank was used for a storage tank of partially digested material pumped out of other tanks. It is evident from the pH values obtained that during the first

\* Paper No. 251 of the Journal Series, New Jersey Agricultural Experiment Stations and New Jersey State Department of Health, Department of Sewage Substation.

four months of operation digestion activities were progressing at an undesirably slow rate with simultaneous production of acid materials. It took considerable time after the tank was allowed to rest to bring the pH value above 7.0 (neutral point) where it remained until the termination of the experiment.

FIGURE I



SHOWING AMMONIA, CARBONATES, TOTAL ACIDITY AND PH IN TANK DURING FIRST 5 MONTHS

#### CARBON DIOXIDE CONTENT

Gas production increased rapidly during the first few weeks of operation with the result that the scum blanket rose considerably and some foaming phenomena began to occur. Simultaneously with increasing gas production the CO<sub>2</sub> content of the gas rose from 4 to 21 per cent in the middle compartment and to 24 per cent at the inlet end. From this point on a decided decrease occurred in CO<sub>2</sub> content which looked at the time very encouraging, especially in view of the fact that the average temperature in the tanks was rising continuously and still better results could be expected. Carbon dioxide content of the gas was always highest from the inlet end with the usual oscillations in the curves. A few complete analyses of the gas made at different dates are given in Table I. The high methane content of the gas is of unusual interest. According to theoretical considerations,

high methane content is desirable in sludge digestion. We recorded methane production ranging from 69.4 to 84.1 per cent; the highest amounts being present at the beginning of the experiment with a decided drop after 14 days. This drop is very significant in view of the calculations given below.

From a number of experiments conducted in the Sewage Experiment Station laboratory on fresh solids digestion, we know that a large proportion of the gas produced at the beginning of digestion consists of CO<sub>2</sub>, followed by a decrease and after sufficient incubation followed again by an increase of CO<sub>2</sub>. The influx of fresh solids after this tank was put into operation accounts for the rise in CO<sub>2</sub>. The decrease in CO<sub>2</sub> content after about one month's operation could be due either to a more rapid "methane digestion" or to an inadequate supply of ripe sludge to cope with the amounts of incoming fresh solids. Ordinarily CO<sub>2</sub> production is high at the beginning when fresh solids alone are digested; when insufficient ripe sludge is present, large and sometimes rapid changes take place.

TABLE I

		Analyses of gases from tank 5			
Date	Days operating	CO <sub>2</sub> %	O <sub>2</sub> %	CH <sub>4</sub> %	N <sub>2</sub> %
April 21	1	4.1	0.0	81.2	14.7
April 23	3	5.6	0.0	84.1	10.3
May 5	14	12.0	0.0	69.4	18.6
June 1	40	18.9	0.0	76.1	5.0
Aug. 18	119	16.2	0.2	78.0	5.6

These changes are due to an unbalanced condition which exists between the different groups of organisms present during the digestion processes. Such an unbalanced condition can cause an enormous increase in CO<sub>2</sub> depending on the groups of organisms which are dominating. This unbalanced condition is sometimes accounted for by the statement that the amount of ripe sludge was possibly inadequate to cope with the incoming fresh solids. It could be said in such case that the desired activities are retarded.

The analyses show a constant increase in bacterial population during the first 6

weeks from 1.4 to 88.5 millions per c.c. The average bacterial population for the first 6 weeks was 31.5 millions per c.c., as contrasted with 64.7 millions during the same period for a tank which had been running continuously. It took 5 months before the bacterial numbers were comparable in the new and old tank. The digesters of solid protein were more numerous in the tank than the hydrogen sulfide producers, but the hydrogen sulfide producers increased at a more constant rate, indicating that the balance between the different organisms governing digestion was not maintained. Moreover, there were some marked rapid fluctuations in numbers of the different organisms.

It is interesting to state that for a long time after refilling, this tank did not have what is regarded as the usual tank fauna. The numbers of protozoa remained comparatively low in spite of the daily influx of animals with the influent. Moreover, out of 18 kinds of protozoa most abundantly present, only 6 have ever been common in other tanks. Most of these forms appeared, increased to a maximum, then declined and disappeared. This tank also showed numerous amebae; at times reaching 8400 per c.c. practically all of one species. Finally, for a long time after refilling, this tank showed living nematode worms. These zoological facts alone offer abundant proof that it took the tank a long time before its physico-chemical state came to an equilibrium recognized as being necessary for efficient digestion.

It was pointed out above that the scum blanket rose rapidly the first 3 weeks accompanied by foaming phenomena. This scum blanket rose most quickly at the inlet end, resulting in actual foaming 22 days after the tank was put in operation. The scum subsided with the change of inlet, to rise again early in July. The sudden increases in bacterial numbers corresponded to the rise of scum. Bacteria able to digest albumen were highest when scum and  $\text{CO}_2$  production were lowest. All these facts together suggested

that the relation between the amount of old sludge and incoming solids was not correct. A few calculations show the actual relations. The total amount of incoming sewage is 3.3 m.g.d. containing about 200 p.p.m. of solids. The capacity of the tank without hoppers up to the slots is 9000 cu. ft. There were 3 tanks in operation receiving about 220 gallons or 29.5 cu. ft. of fresh solids on dry basis per tank per day. The amount of old sludge used for seeding was approximately 3750 cu. ft. (95 per cent moisture) so that the total sludge present on the basis of dry solids was 187.5 cu. ft. The total incoming solids were 29.4 cu. ft. or 15.7 per cent of the sludge present, assuming that the specific gravity of the dry fresh solids is the same as that of the dried sludge, or in other words, the addition was 1 part of dry fresh solids to 6.37 parts of dry sludge every 24 hours.

A series of laboratory experiments conducted under controlled conditions, to determine the optimum amount of fresh solids which can be handled by a given quantity of old sludge, gave a fairly definite insight as to what happens when too much fresh solids are added. In these experiments certain definite quantities of fresh solids were added daily to known amounts of ripe sludge and the progress of digestion closely studied for about 4 months. The additions of fresh solids were daily 5, 10, 15 and 20 per cent by volume, or 1, 2, 3 and 4 per cent on a dry solids basis. The detailed figures and discussion of this experiment will be published in the forthcoming annual report of the New Jersey Sewage Experiment Station, and it will suffice to state here some general conclusions.

A comparison of the chemical, bacteriological and zoological data obtained emphasized one outstanding fact: the ash content of the mixed solids in process of digestion and the numbers of bacteria and protozoa increased with the addition of fresh solids up to a certain percentage. Beyond that point there was no further

proportional increase, but the ash content and bacteria decreased, while protozoa remained constant. This point is near an addition of 2 per cent on the dry basis or 10 per cent by volume of fresh solids. At this point there is not only a high average of bacteria and a remarkable smoothness of the bacteriological curve, but also a similar smoothness in the curve for ash content and reduction of solids. These phenomena seem to indicate that this point of equilibrium is the optimum for producing a balanced condition or most efficient digestion. As soon as more fresh solids are added, this balanced condition is upset and irregularities in the curves for bacteria, chemical products and protozoa make their appearance. With additions of 1 per cent fresh solids there is a maximum increase in bacteria and ash content, but the plotted curves show that the increase is erratic, indicating a situation similar to larger additions of fresh solids but on the other side of the optimum balanced condition. However, these smaller quantities can be handled efficiently without causing any undesirable disturbance. This condition might be expressed by saying that the tank is running below its possible capacity.

It has been assumed, and our experiments seem to bear out this assumption, that it takes approximately 30 days for minimum satisfactory digestion of fresh solids if sufficient ripe sludge is present to overbalance the incoming material. The experiments briefly discussed above show that if 2 parts of dry fresh solids are added daily to 98 parts of ripe sludge (dry basis) digestion takes a normal course, while when 3 parts are added digestion is impaired. With the addition of 4 per cent dry fresh solids, the sludge changes color gradually from black to a peculiar greenish hue and later to yellowish brown, becoming acid with an obnoxious odor. Calculations carried out by Mr. Downes on the basis of his figures presented in his discussion of Mr. Eddy's

paper referred to at the beginning of this article, agree markedly with our laboratory findings. He calculated that additions of 2 per cent daily are about the limit the tanks can handle.

Returning to the discussion on the altered tank, we found that the tank started to foam 22 days after it was put into operation. A decided drop in proportion of methane produced occurred 14 days after the tank was started. If 30 days digestion is taken as criterion it would seem that only enough ripe sludge was present to take care of about 14 days' addition of fresh solids. It seems clear therefore that the relation between ripe sludge and fresh solids is fairly definite and should be kept as nearly constant as practical operation will allow, and that a change in the construction of a tank as such has no value whatsoever if this relation is not taken into account. It is also clear that computing the required capacity of a sludge compartment in terms of cubic feet per capita must necessarily be inadequate. Mr. Eddy has already pointed out that in such a comparison the effects of temperature also have to be reckoned with.

Finally, it may be concluded that foaming is primarily caused by an incorrect relation between old sludge and fresh solids, which can be aggravated by the reaction of the tank contents. Other factors like excessive grease, excessive masses of carbohydrates (mash from illicit distilleries), etc., may at times upset the balance in the tank temporarily, or when the balance is at a critical point cause more permanent troubles.

Experiments are now under way in our laboratory to determine the optimum reaction of the material in the tanks for efficient digestion and a study of the means to correct the reaction to the desired point.

#### REFERENCES

1. Eddy, H. P. *Transactions Am. Soc. Civil Engrs.*, Vol. 58, 1925, pp. 465, 510.
2. *Loc. cit.*, p. 514.
3. *Loc. cit.*, p. 535.